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Investigation of magnetic loop structures in the corona of UX Arietis

M. Massi and E. Ros

Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

Abstract. Most of the emission coming from the solar corona is confined into closed magnetic structures in the form of arcs (loops). Very little is known about the structure of stellar coronae. The magnetic topology, however, can be inferred by studying the radio emission coming from electrons trapped in the magnetic loops. Evident morphological changes are produced in fact by stellar rotation. We have performed 4 VLBA+Effelsberg runs distributed in time so as to cover well the rotational period of 6.44 days of the active star UX Arietis. We present here some preliminary results, from those observations.

1. Large magnetic loops in stellar coronae

RS CVn stars are binary systems characterized by intense coronal activity at X-rays, UV and radio wavelengths. One of the most active sources at radio wavelengths is the system UX Arietis (see Franciosini et al. 1999 and references therein). Its strong activity is attributed to magnetic fields which are generated in the stellar interior by a dynamo mechanism, and emerge from the stellar surface in typical arc-like structures (loops; see Parker 1955; 1979). Since the enhancement of the magnetic field partially blocks the convective energy transport from below, the foot-points of an emerging loop appear as dark spots in visible light (Skinner et al. 1997). A few and quite large spots on UX Arietis have been observed by Vogt & Hatzes (1991) and Elias et al. (1995): a polar spot and 2 equatorial spots. The spots are very large in comparison with those on the Sun, covering almost 20% of the stellar surface. Large spots could imply large sizes for the interconnecting loops. Extended loops on RS CVn systems, with dimensions much larger than the stellar radius are inferred also from X-ray observations of eclipsing binaries (Walter et al. 1988).

Observational evidence of large structures with sizes comparable to the binary system comes from VLBI observations of UX Arietis (Mutel et al. 1985; Massi et al. 1988; Beasley & Bastian 1996; Massi et al. 1999). Those studies found components with sizes of almost 2 milliarcseconds (mas), corresponding to a linear size of 1.5×10^{12} cm at the distance of 50 pc), comparable with the orbital size of the system (about 1.3×10^{12} cm). The observed radio emission is caused by gyro-synchrotron radiation from mildly relativistic electrons, that accelerated during flares remain trapped inside the magnetic loops.

2. Magnetic loops anchored on a rotating star

We have performed VLBA+Effelsberg observations of the system UX Arietis during four almost consecutive days: 23, 25, 26 and 27 September 2001. We observed at 8.4 GHz, recording at an aggregate data bit rate of $128\,\mathrm{Mb\,s^{-1}}$ with dual polarization. We interleaved cross-scan measurements at the 100 m antenna in Effelsberg during the VLBI observations to monitor the total flux density of UX Arietis. We covered a time interval of six hours for each run, resulting in a total $\sim$4 hr of observing time spent on UX Arietis in each run. The source was flaring during the observations. Therefore, in order to distinguish the variability effects from structural changes we divide the data into different time slots of 1 hr length on the basis of the Effelsberg total flux density monitoring.

We have used DIFMAP to perform a best-fit of the visibility data using elliptical Gaussian components. As an example of our procedure we show in Fig. 1 the result of the model fitting of three consecutive data sets of September 26th corresponding to the UT intervals 04:00-04:50, 05:00-05:50, and 06:00-06:50, respectively. A two Gaussian component model is sufficient for all three data sets. However, as one can see in Fig. 1, while the sizes of the two components do not change much from hour to hour, their relative positions and orientation evidently show evident changes.

As discussed above, the optical observations proved the existence of a large polar spot and of other two spots at the equator. Either the spots are rather stable or is stable the longitude/latitude of their emergence region is unchanged (Massi et al. 1998). Therefore, we may interpret the two fitted Gaussian components as being due to radio emission of electrons trapped into two magnetic loops: one "longitudinal" connecting polar spots, the other "equatorial" connecting equatorial spots. As the star rotates, the loops change their relative position and orientation with respect to the line of sight, causing the observed variability of the source structure.

This interpretation can be tested not only by examining variations from day to day (as in Franciosini et al. 1999 and in Massi et al. 1999) but even in variations from hour to hour. Already in the 3 maps presented here (of the 16 available maps: 4 hours×4 days), one sees how morphological changes of the source structure are consistent with

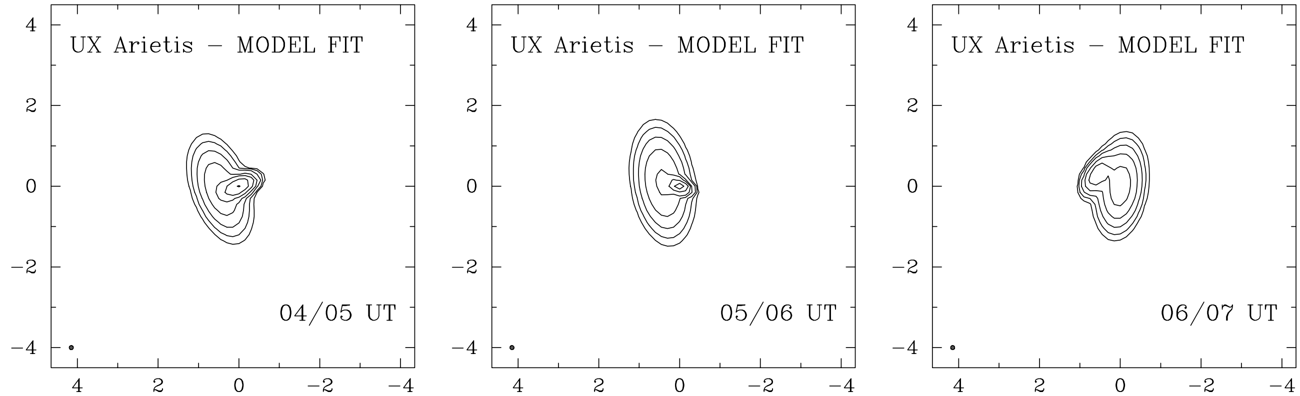

Fig. 1. Simulated images with the (u, v)-model fitting results of the three data set of September 26th corresponding to the UT intervals 04:00-04:50, 05:00-05:50, and 06:00-06:50, respectively. The visibility function of all three data sets is well fitted by two Gaussian components. The sizes of the two components do not change much from hour to hour, but an evident change occur in their relative position and orientation. The origin of this evolution can be explained by geometrical factors (i.e. star rotation).

changes of the relative position of the two loops: one of the two (the longitudinal one) probably crosses the line of sight during the star rotation. More details will be provided in Massi & Ros (in preparation).

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